AD-A105 129 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/G 5/1
AN EVALUATION OF MIL-PRIME IN COMPARISON WITH THE TRADITIONAL S--ETC(U)
JUN 81 R T STEARMAN, W E WEBER
UNCLASSIFIED AFIT-LSSR-4-81 NL

1 OF 2
AD A
105129

LEVEL II

ADA105129

DTIC
ELECTE
OCT 6 1981
S D
A

This document has been approved for public release and sale; its distribution is unlimited.

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (ATC)
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

FILE COPY

81 10 6 188

AN EVALUATION OF MIL-PRIME IN COMPARISON WITH THE TRADITIONAL SPECIFICATION SYSTEM

Ricky T. Stearman, Captain, USAF
Warren E. Weber, Major, USAF

LSSR 4-81

The contents of the document are technically accurate, and no sensitive items, detrimental ideas, or deleterious information are contained therein. Furthermore, the views expressed in the document are those of the author(s) and do not necessarily reflect the views of the School of Systems and Logistics, the Air University, the Air Training Command, the United States Air Force, or the Department of Defense.

A

AFIT Control Number LSSR 4-81

AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to determine the potential for current and future applications of AFIT thesis research. Please return completed questionnaires to: AFIT/LSH, Wright-Patterson AFB, Ohio 45433.

1. Did this research contribute to a current Air Force project?

   a. Yes   b. No

2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not researched it?

   a. Yes   b. No

3. The benefits of AFIT research can often be expressed by the equivalent value that your agency received by virtue of AFIT performing the research. Can you estimate what this research would have cost if it had been accomplished under contract or if it had been done in-house in terms of manpower and/or dollars?

   a. Man-years ________ $ ________ (Contract).

   b. Man-years ________ $ ________ (In-house).

4. Often it is not possible to attach equivalent dollar values to research, although the results of the research may, in fact, be important. Whether or not you were able to establish an equivalent value for this research (3 above), what is your estimate of its significance?

   a. Highly Significant   b. Significant   c. Slightly Significant   d. Of No Significance

5. Comments:

______________________________   ______________________________
Name and Grade   Position

______________________________   ______________________________
Organization   Location

FOLD DOWN ON OUTSIDE - SEAL WITH TAPE

AFIT/ LSH
WRIGHT-PATTERSON AFB OH 45433

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE. $300

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 73236 WASHINGTON D.C.

POSTAGE WILL BE PAID BY ADDRESSEE

AFIT/ DAA
Wright-Patterson AFB OH 45433

FOLD IN

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

14 AFIT

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER LSSR-4-81	2. GOVT ACCESSION NO. AD-A105	3. RECIPIENT'S CATALOG NUMBER 729
4. TITLE (and Subtitle) (6) AN EVALUATION OF MIL-PRIME IN COMPARISON WITH THE TRADITIONAL SPECIFICATION SYSTEM		5. TYPE OF REPORT & PERIOD COVERED (9) Master's Thesis
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Ricky T. Stearman, Captain, USAF Warren E. Weber, Major, USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS School of Systems and Logistics Air Force Institute of Technology, WPAFB OH		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (12) 92
11. CONTROLLING OFFICE NAME AND ADDRESS (11) Department of Communication and Humanities AFIT/LSH, WPAFB OH 45433		12. REPORT DATE June 1981
		13. NUMBER OF PAGES 85
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Air Force Institute of Technology (ATC) Wright-Patterson AFB, OH 45433		
18. SUPPLEMENTARY NOTES APPROVED FOR PUBLIC RELEASE AFR 190-17. Fredric C. Lynch FREDRIC C. LYNCH, Major, USAF Director of Public Affairs 7 AUG 1981		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Mil-Prime Specifications Requirements Requirements Document Performance Specifications		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Thesis Chairman: Lieutenant Colonel Ronald G. Blackledge		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED 012350

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Mil-Prime is a relatively new Air Force concept for writing contract specifications. Its intent is to emphasize the writing of requirements and their verification in functional terms related as closely as possible to a system's mission. The implementation of Mil-Prime was studied on the C-X landing gear and compared to the old procedures used on the C-5 landing gear. The AFIT thesis concluded that there are some inherent advantages in using Mil-Prime. It also concluded that several areas will continue to require close scrutiny and development if Mil-Prime is to be effective.

LSSR 4-81

AN EVALUATION OF MIL-PRIME IN COMPARISON WITH THE TRADITIONAL SPECIFICATION SYSTEM

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Ricky T. Stearman, BS
Captain, USAF

Warren E. Weber, BS
Major, USAF

June 1981

Approved for public release;
distribution unlimited

This thesis, written by

Captain Ricky T. Stearman

and

Major Warren E. Weber

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 17 June 1981

COMMITTEE CHAIRMAN

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance, advice, guidance, and patience of Lieutenant Colonel Ronald Blackledge, our thesis advisor, who helped to clear the muddy waters in our search for the answers to our questions. Furthermore, we gratefully acknowledge the generous cooperation and contributions made by the personnel of ASD/EN, especially Mr. Joseph Weingarten for the time he took in assisting in this research effort and the valuable information he passed on to us concerning the Mil-Prime effort.

Additionally, we owe a great amount of thanks to our wives, Alice and Terri, for being mother and father to our children while we were plowing through the endless proliferation of learning opportunities. And last but certainly not least, we thank Suzanne Weber for accepting this thesis on short notice and for doing an outstanding job of typing.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In the years since World War II, the sophistication and cost of new weapon systems have steadily increased. The relatively inexpensive machine guns and gravity bombs of the World War II era have largely been replaced by infrared, electro-optical, and laser guided munitions, which in many cases cost over $1 million a copy. In this same period, the American people have demanded a better accounting of their tax dollars to ensure that these dollars are spent as effectively and efficiently as possible.

It is increasingly important for the Air Force to buy weapon systems that are cost effective. The Air Force must continue to cut costs while maintaining a high degree of technical sophistication and reliability. The Aeronautical Systems Division (ASD), Wright-Patterson AFB, Ohio, which buys Air Force aeronautical weapon systems and subsystems, is a leader in cutting costs. Lt. Gen. Lawrence A. Skantze, ASD Commander, states:

> We are at the forefront of the Air Force's effort to mold new and existing technologies into superior weapon systems for our operational forces. We must meet this challenge in our era of tremendous budget pressures, where inflation and shrinking real dollar value limit us to fewer systems and smaller quantities.... Our goal is to produce both mission effective and cost effective aeronautical systems [13:37].

The costs of major weapon systems are driven, in part, by the following factors: attempts to deploy systems with new technology and high performance; low rates of production due to budget constraints and desires to maintain active production bases as long as possible; absence of price competition between contractors; lack of real motivation on the part of contractors to reduce costs; the impact of socio-economic programs, Government controls, and red tape; and a nationwide problem of reduced research and development expenditures and lessening of productivity (18:i).

Each of these factors could be subdivided into potential research topics. One aspect of the factor entitled "lack of real motivation on the part of contractors to reduce costs" is the barrier to innovation and creativity often caused by the specifications which are incorporated into the contracts for the weapon systems. These specifications, which define the performance and design characteristics of the weapon system, e.g. how fast and how far an aircraft must fly, are a major cost driver and, therefore, an important topic for research.

The specifications, along with the work statement, drawings, and item description, formulate the very heart of any request for proposal (RFP) and subsequent contract. Whether or not a contract will be successfully performed is quite often determined not at the time the contract is negotiated or the award made, but rather at the time the purchase or performance description is written (6:65). This thesis

describes both the traditional process by which the U.S. Air Force specifies the requirements for its new aeronautical weapon systems and subsystems, and a new specification-writing process entitled "Mil-Prime," and then compares the two processes.

There are approximately 45,500 military specifications and standards in the Department of Defense (DoD) library, each of which specifies numerous requirements with which defense contractors must comply. Of the 45,500 traditional specifications and standards, approximately 40,000 were written primarily for reprocurement purposes, and only approximately 500 specifications are considered to be key documents to be used in the acquisition of aeronautical weapon systems. These 500 documents, which, in turn, reference other documents, are very important because ASD has been using these specifications as the basis for its technical requirements, spending over $1.3 billion in research and development funds and approximately $4.8 billion in production funds each year to buy aeronautical systems and subsystems (21).

The 45,500 traditional specifications and standards are generalized documents, i.e. they are not specifications for specific weapon systems. These 45,500 documents fall into three categories: reprocurement, development, and general design. The reprocurement category is by far the largest in terms of numbers of documents. The development category includes the system specifications and subsystem specifications. The development category also includes the MIL-STD-490 Part I

and Part II configuration item specifications for specific weapon systems, but this latter set of specifications is in addition to and separate from the 45,500 traditional specifications. The general design category includes those standards, e.g. reliability, maintainability, and quality assurance, sections of which are lifted out of and incorporated by reference into development specifications. The focus of this thesis is on development specifications.

Definitions

1. Development specifications: the documents used by the research, development, and acquisition community within the DoD to specify how new products are to function and/or be built.

> Development specifications state the requirements for the design or engineering development of a product during the development period. Each development specification shall be in sufficient detail to describe effectively the performance characteristics that each configuration item is to achieve when a developed item is to evolve into a detail design for production [17:3].

2. Reprocurement: the process of contracting for items which have already been developed by requiring compliance with "build-to" specifications (see Type II specifications below).

3. Subsystem Requirements Document: a document prepared by the Government, and incorporated into the request for proposal, which establishes the performance requirements for an aircraft's subsystems. The selected contractor will later transform this document into an air vehicle specification (11).

4. Technical Requirement: the link in contract specifications between high order conceptual program goals and specific design detail (2:28).

5. Type I (Part I) specification: a development specification which states the complete performance requirements of the product for the intended use; also called a "functional specification," a "design-to specification," and a "performance specification" (16:45).

6. Type II (Part II) specification: a specification which describes, in detail, the complete requirements for an item, including the materials to be used, their sizes and shapes, and how the item is to be fabricated and built. It provides a completely defined item, capable of manufacture by a competent manufacturer in the industry (6:66); also called a "build-to specification."

Problem Statement

Traditional military development specifications inhibit the flexibility of the process that is used to design new aeronautical systems. The mixture of performance and design characteristics in Type I and other published military system and subsystem specifications constrict the design flexibility of defense contractors (see Background for elaboration).

Background

Mr. Joseph Weingarten is the program manager in ASD for the development of a new approach to aeronautical specifications. According to Mr. Weingarten, the gradual development

of the 45,500 generalized specifications currently in the DoD system has caused numerous implementation problems. Some of the problems, as reported by users of these specifications, involve facets of design flexibility and are as follows (21):

1. One specification often requires by reference the incorporation of other specifications. Referencing to a limited extent is certainly more desirable than repeating verbatim the words from another specification, but this tiering of specifications has in many cases become excessive. For example, one specification requires in its second tier the incorporation by reference of 3,111 other specifications.

2. The specifications are difficult to tailor to specific weapon systems being acquired. The Government engineer tends to require the potential contractors to accept a specification in its entirety, even if the mission that the aircraft is to support does not require the incorporation of the complete specification.

3. The specifications inhibit innovation. The specifications are conceived to be cast in concrete, even if the concepts incorporated in them have to be superseded by new technology.

4. The requirements in the specifications are often not practically verifiable. Two examples of this problem are as follows: a) MIL-B-8584 requires that an aircraft parking brake hold an aircraft on an 18° slope, but there is not any verification section for this requirements, which means that a contractor would not be obligated to test his design to see if it meets this requirement; b) MIL-A-8865 limits the pounds per

square inch of allowable pressure on the bottom of a fuselage that is ditched in the water, but there is not any corresponding verification section, and furthermore, there is not any requirement for the aircraft to remain afloat long enough for the crew and passengers to evacuate once the aircraft is in the water.

5. Specifications are sometimes gold-plated. Less expensive methods to build a part with the same function are prohibited by rigid adherence to the specifications. Gold-plating can also refer to a requirement that is impossible to meet. For example, MIL-L-38207 requires that the material covering the clock mainspring in an aircraft cockpit be made of an "unbreakable" alloy.

6. Specifications are often not understood by the user. A requirement that may have been a necessity in the past is now no longer necessary because of advanced technology, but still may be specified as a requirement. For example, MIL-L-58207 requires cockpit clocks to have 15 jewels, and hands for the seconds, minutes, and hours, rather than specifying what the accuracy of the clocks should be. This means that a contractor who proposes an old style clock which would not keep accurate time would be considered responsive, whereas a contractor who proposed a highly accurate solid state digital clock would be considered unresponsive, unless the latter contractor somehow incorporated hands and 15 jewels into his digital clock.

7. The rationale for the requirement in a specification may be lacking, which makes people reticent to change the

specification because they do not understand the intent of the original writer.

These examples of implementation problems highlight the need to improve the traditional system for writing specifications.

OMB Circular A-109

Impetus towards the development of an improved system for writing development specifications was provided in April 1976 with the issuance of Circular A-109 by the Office of Management and Budget (OMB). This circular requires the agencies of the Federal Government, including the DoD, to think more in terms of specifying mission requirements that need to be satisfied rather than in terms of equipment needed to satisfy a mission. The equipment needed is defined by technical specifications. The A-109 requirement to specify development requirements in terms of mission needs should alleviate many of the specification problems noted earlier since many of the problems were caused by specifying requirements in terms of hardware needs.

The implementation of A-109 in the DoD has led to a new approach to the traditional application of standards and specifications into military contracts. Prior to the issuance of A-109, a Deputy Secretary of Defense Clements memorandum dated 8 August 1975 entitled, "Specification/Standards Application," charged the Defense Science Board Task Force with the review of military standards and specifications. The

Defense Science Board Task Force issued a report in April 1977 which recommended an immediate program throughout DoD to improve specifications to satisfy the A-109 needs (21). This recommendation echoed an earlier Office of Federal Procurement Policy recommendation to tailor specifications and standards to avoid nonessential constraints on contractors--specification tailoring is a forerunner of Mil-Prime (20:11).

A-109, in fact, requires the tailoring of specifications and standards, i.e. the selective application of parts of specifications and standards, during certain phases of the major system acquisition cycle in which the Government interacts with contractors. The major system acquisition cycle, according to the Office of Federal Procurement Policy, consists of the following seven phases: mission analysis; evaluation and reconciliation of needs; exploration of alternative systems; competitive demonstrations; full-scale development, test and evaluation; production; and deployment and operation (19:4). These seven phases, which are described in Appendix A, are collapsed into four phases by the Department of Defense as follows: conceptual, validation, full-scale development, and production; but the concept of a multi-phased acquisition cycle does not change (2:55-56).

During the "exploration of alternative systems" phase, which is the conceptual stage of the major weapon system acquisition cycle, the program manager's acquisition strategy must consider the tailoring of the specifications and standards (19:11); and the Government solicitation requesting alternative

systems must not restrict the contractors by specifying or referencing Government specifications and standards (19:14). During the "competitive demonstration" phase, which is the demonstration/validation stage of the weapon system acquisition cycle:

> Contractors should not be restricted by imposing arbitrary compliance with Government specifications and standards. Such may be referenced, but alternatives which might lead to a better system should be encouraged [19:18].

Literature Review

The U.S. Government has been aware of the problems caused by the vast number of specifications and their rigid application. In July 1969, James H. Flanagan, Office of the Scientific Director, U.S. Army Natick Laboratories, wrote an article criticizing the number of specifications that the Government uses.

> . . . That the real problem with specifications today is that there are far too many and that there is an insufficient number of technically qualified personnel to properly service the inventory [4:13].

In 1973, General Brown, while Commander of Air Force Systems Command, convened a high-level workshop called Project ACE (Acquisition Cost Evaluation), which identified many problems in the acquisition of weapon systems. Among these problems was the excessive application of military specifications. The cause of the excessive application, per the Project ACE conclusions, was the inexperience of the engineers who were required to apply the specifications (1:2).

By 1977 the concern over specifications shifted from

trying to educate the engineers to the "tailoring" of specifications. The Defense Science Board (DSB), established by Deputy Secretary of Defense Clement in 1974 to study how to improve the origination, generation, maintenance, and application of specifications, concluded in April 1977 that specifications were still being misinterpreted and misapplied. The Board was composed of representatives from the Office of the Secretary of Defense, the three military services, the Defense Logistics Agency, and civilian industry. The Board found that:

> In general, the documents (specifications) contain much more flexibility than appears to be used in practice. Most of the instances of "excessive cost" examined by the Task Force resulted from a failure to utilize this flexibility in a reasonable way, rather than a fundamental problem with the specification itself [12:vii].

The Board recommended that both industry and government "stop treating the specifications as sacred [12:17]," and tailor the required specifications to the particular needs of a given program.

> The Government program manager and the functional organizations which support him must be educated and motivated to realize that strict, parochial application of specifications and standards is neither required nor desired [12:vii].

The Board also agreed that many specifications required rewriting or elimination because of obsolescence, inflexibility, and difficulty of interpretation. As an example, the Board cited the 15-page specification for chewing gum (12:15-17).

In April 1977, DoD issued a new directive, DODD 4120.21, addressing the tailoring of military specifications

and standards. It directed the services to impose only essential systems needs, to avoid blanket contractual imposition, and to solicit recommendations from prospective contractors (9:14).

Tailoring became the pet word of the acquisition community for a time, but results were often lacking because there were far too many specifications incorporated in a RFP that would have to be tailored prior to the RFP's issuance. Furthermore, it was difficult to determine, in advance, which specifications would present problems as development progressed. Even the DSB realized the impossibility of tailoring all the specifications called for in a RFP, and the increase in manhours that would be expended attempting to tailor only the most important ones (9:15).

It was also found that specification tailoring was time consuming and risky for both buyer and seller. The government buyer put his career on the line when tailoring since he would no longer have the safety of falling back upon the standardized specification if the tailored approach could not be implemented by the contractor. The contractor would put the prospect of winning the contract in jeopardy by appearing non-responsive by not strictly complying with all specifications in the RFP (7:112). These problems were identified, articles were written, and solutions were offered, but to date little has changed since the Defense Science Board first advanced their recommendations.

Also in 1977, Daniel E. Strayer and Lyle W. Lockwood

published a paper entitled "What Are We Buying Here?," which focused on the technical requirements specified in Air Force contracts. Strayer and Lockwood maintain that the acquisition process has been the subject of much research and systematic attention, but that the real driver to cost growth is the technical requirements specified in contracts, which has been relatively ignored by other researchers. Strayer and Lockwood proposed a taxonomy of terms to define in detail the technical requirements specified in Air Force weapon systems contracts. This taxonomy includes the following terms: mission requirements, operational characteristics requirements, and design standards and specifications (14:2).

Ronald G. Blackledge published a Ph.D. dissertation in 1979 which used the Strayer-Lockwood taxonomy as a basis to define and measure a contract's technical requirements. Blackledge modified the Strayer-Lockwood taxonomy both by expanding the definition of operating characteristics requirements and by adding interface requirements to the taxonomy (2:52-53). Blackledge's basic research, which was not as conclusive as he had hoped, is the latest known research into the subject of defining technical requirements.

Mil-Prime

OMB Circular A-109, as mentioned earlier, requires a mission orientation in the weapon system acquisition process in lieu of the former hardware orientation. ASD initiated an effort in January 1976, independent of the Defense Science

Board Task Force, Strayer-Lockwood, and Blackledge efforts, to correct the numerous implementation problems caused by the way in which specifications for aeronautical systems have been written. This effort was ASD's own response to Deputy Secretary of Defense Clements' 8 August 1975 memorandum to review military standards and specifications. Clements' memorandum called for more attention to the development and maintenance of specifications before the issuance of requests for proposals, policies to avoid the blanket use of specifications, and most important, the necessity to force technical activities to "scrub and tailor" specifications (21).

ASD's response to the Clements memorandum was a decision to modify its aeronautical specifications in a format that would force its engineers to tailor the requirements. This modification effort is entitled "Mil-Prime." The Mil-Prime effort focuses on providing development specifications associated with aeronautical weapon systems.

The Mil-Prime effort is divided into three types of development documents: specifications, standards, and handbooks (20:3). Mil-Prime specifications state operational needs, general parameters, and interface requirements for a physical product family. The specific values applicable to the weapon system to be acquired, e.g. the range, altitude, frequencies, etc., are filled in by the responsible Government engineer before the issuance of the request for proposal. This "fill in the blank" concept forces specification tailoring.

The Mil-Prime specification becomes the Government's

Type I specification, formerly called a Part I specification. The Type I specification incorporates only performance requirements, as determined by the mission, the operational need, and interface requirements. The Type II specification is the "build-to" design specification, which will be developed using the Mil-Prime specifications by the winning contractor as part of the product development process. The end items of a contract would include the hardware, and the Type II specification for reprocurement purposes (21).

The Mil-Prime standards provide the criteria and qualities applicable to a physical product, but are not used to acquire any actual product. For example, Mil-Prime standards will be developed for reliability and maintainability requirements.

The Mil-Prime handbooks contain technical rationale for each specification and standard, provide guidance for applying the specifications and standards, and are a depository for lessons learned in each technical area. The handbooks explain where a requirement came from and why the requirement is still valid. The handbooks will serve as the logical departure point for arguments about the validity of imposed requirements because the origin of the requirements will, for the first time, be readily available. Each handbook will also identify the Government engineer who is responsible for monitoring the handbook, which is a radical departure from the old concept in which a Government engineer could resist changes by hiding behind a shield of anonymity.

The relationship among these three Mil-Prime documents--the specification, standard, and handbook--may be clarified by means of the following example. The Mil-Prime specification for aircraft "fuel systems," MIL-F-87154 (USAF) dated 15 August 1980, includes in paragraph number 3, entitled "Requirements," subparagraph number 3.1.1.2, as follows: "Flow performance. Fuel flow performance of each engine feed system shall be ______." The blank would be filled in by the responsible Government engineer as he tailors the Mil-Prime fuel systems specification to the specific aircraft system which he is helping to design. Paragraph number 4, entitled "Quality Assurance Provision," of the same specification has a subparagraph number 4.1.1.2, which reads as follows: "Flow performance. Fuel flow performance for each engine feed subsystem shall be verified by ______." The blank is again filled in by the responsible Government engineer.

The Mil-Prime handbook for aircraft fuel systems includes the following information:

> 3.1.1.2 Flow performance. Fuel flow performance of each engine feed system shall be __________.
>
> RATIONALE
>
> Fuel flow requirements vary with airspeed, altitude, gross weight, aircraft configuration, and other variables.
>
> GUIDANCE
>
> For single engine aircraft the feed system should provide flow for 100 percent of the maximum fuel consumption of the engine in addition to any fuel

flow for cooling purposes and motive flow for fuel driven pumps. For multiple engine aircraft, a feed system must provide flow for cross-feed of at least one additional engine at full power; therefore, the engine feed system should provide a minimum of 200 percent of the maximum fuel consumption of the engine plus any fuel flow required for cooling.

LESSONS LEARNED

Potential growth fuel flow should be included in determining flow performance. Fuel flow growth for transport type aircraft is a real possibility.

Verification:

4.1.1.2 Fuel flow performance of each engine feed subsystem shall be verified by ____________________.

Verification guidance/rationale:

The flow performance of each engine feed system should be verified by analyses and tests on a simulator and during flight tests.

LESSONS LEARNED

Both fuel temperature and altitude as well as rate of change of altitude have a great effect on the ability of the feed system to deliver fuel. These critical parameters should be clearly stated in the test procedures. Flow performance tests should be conducted in association with fuel availability tests.

A Mil-Prime standard for reliability provides the reliability requirements for the overall aircraft system. Paragraph 3.5 of the Mil-Prime fuel systems specification provides the specific reliability requirements for the fuel system, and paragraph 4.5 of the same specification provides the mean by which the specific reliability requirements may be verified.

The Mil-Prime specifications and standards are part of the specification tree in weapon systems acquisitions. For

example, Fig. 1 is a specification tree for a hypothetical new fighter called the F-X. The engine (F-101), inertial navigation system (F^3INS), and radio (ARC-164) of the F-X are imposed requirements on the F-X contractors. These specification requirements are levied to satisfy the Air Force's objectives of lower unit costs, better reliability and maintainability, and standardization. One significant difference between the traditional system and Mil-Prime is apparent in the structures, fuel system, radar, and simulator specifications. Now the contractor or contractors have great design latitude that they did not have before because of the specific mandatory requirements imposed by the traditional aeronautical specifications. Another significant difference is apparent in the flying qualities and "ilities," e.g. reliability, maintainability, quality, etc., standards. The traditional standards, unlike the Mil-Prime standards, do not incorporate a separate "lessons learned" section. Engineers using the Mil-Prime standards are provided with a handbook containing "lessons learned," including the reasons why certain requirements and verification techniques are called for in section 3 and 4.

The result of the Mil-Prime effort should be that the numerous technical requirements of Air Force aeronautical research and development contracts which drive cost growth will be brought under control, which in turn should help bring the cost growth of major weapon systems under control. In the process, Mil-Prime will provide a specification system that is responsive to the needs of the using commands; that provides

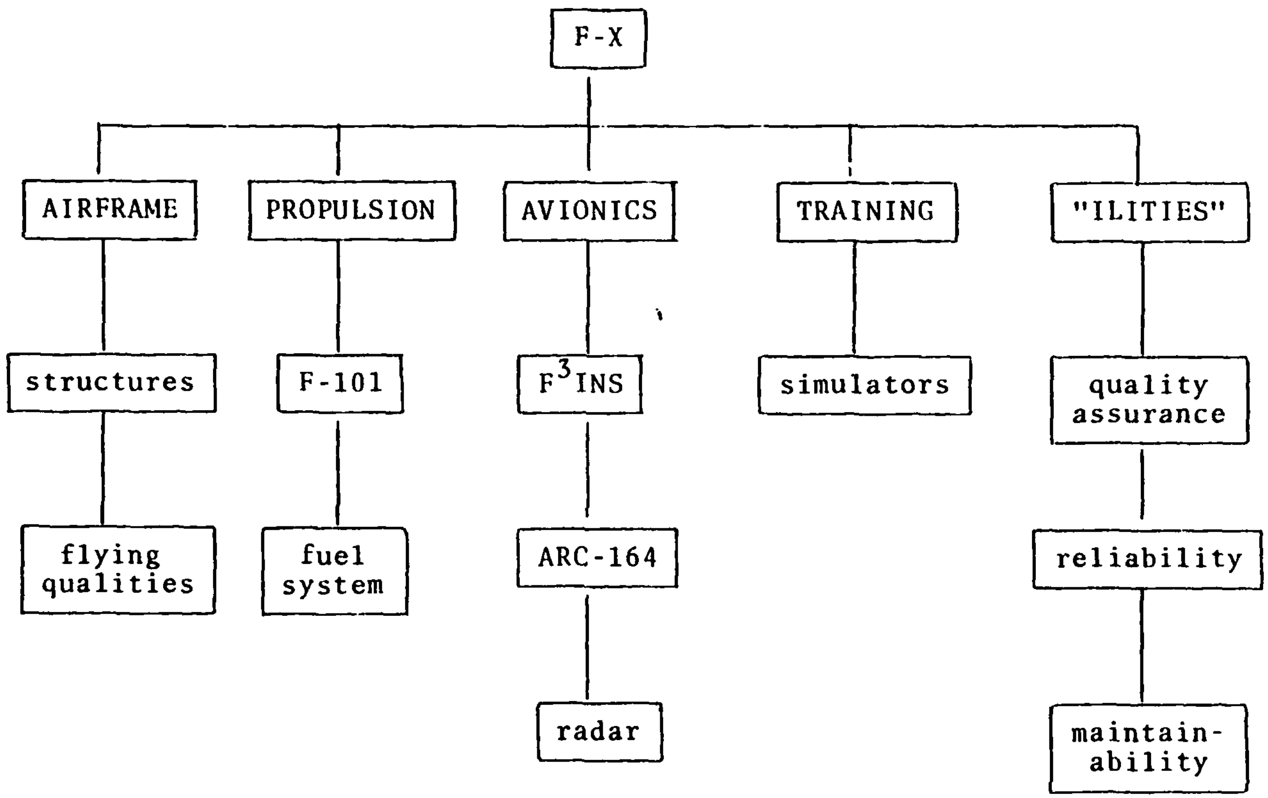

Fig 1. F-X Specification Tree

opportunities for innovation; that establishes a repository for lessons learned; that provides feedback to Government engineers; that reduces over specifying, tiering, and paperwork; and that accomplishes the DoD objectives as stated by the 8 August 1975 Clements memorandum.

Currently there are approximately 60 aeronautical specifications which ASD has decided to rewrite in the Mil-Prime format. The Mil-Prime effort is targeted for completion in 1982. As of 29 April 1981, ASD had expended 24,000 manhours developing the Mil-Prime documents, but had succeeded in completing only five of the 60 documents; however, twelve additional documents were in completed draft and over 40 others were underway (21).

The first request for proposal (RFP) using any Mil-Prime document was issued in October 1980. This RFP, for the C-X aircraft, incorporates a specification that was written by some of the engineers who were currently drafting the 60 Mil-Prime documents, with the result that the specifications for certain subsystems of the C-X aircraft have been written using the Mil-Prime format as a guide. The results of the C-X specification writing effort are available for evaluation.

Research Objective

The research objective of this thesis is to document and describe the potential flexibility and simplicity of the proposed new Mil-Prime system by comparing one set of Mil-Prime documents with a similar set of traditional specifications.

Research Questions

1. How are the characteristics of the Mil-Prime system implemented into actual Type I performance specifications?

2. What are some relevant differences between the new specification and the traditional Type I specifications?

3. What is the flexibility and simplicity impact of the Mil-Prime documents resulting from these differences?

CHAPTER II

METHODOLOGY

The Mil-Prime effort consists of specifications, standards, and handbooks. The specifications state the operational needs, general parameters, and interface requirements for a physical product family. The Mil-Prime specification, which becomes the Government's Type I specification, incorporates specific performance requirements applicable to the weapon system to be acquired. These requirements are determined by the responsible Government engineer, and are incorporated into the request for proposal (RFP). This Mil-Prime process forces specification tailoring.

The RFP presents to a contractor the performance criteria that is desired by the requesting DoD agency. Included in the RFP is the general specification, which is a compilation of all of the individual subsystem specifications.

The Mil-Prime standards provide the criteria and qualities applicable to a physical product, but are not used to acquire any actual product. The Mil-Prime handbooks contain the technical rationale, the origins, and reasons for both the specifications and standards. It also identifies the Government engineer responsible for overseeing the handbook, and is a repository for lessons learned in each technical area.

There are approximately 60 aeronautical specifications, e.g. the landing gear specification, the environmental control system specification, the fuel systems specification, etc., which ASD has decided to rewrite in the Mil-Prime format. A thorough evaluation of Mil-Prime in comparison with the traditional specification writing system starts with a rigorous comparative evaluation of one or more of the 60 aeronautical specifications that are being rewritten. The research questions in Chapter I propose this comparative evaluation in high level conceptual terms.

To better answer these questions, the research questions are broken down into their most elemental parts, from which a broad conceptual model and a more specific operational model of each research question are formulated.

Research Questions

The first research question is: "How are the characteristics of the Mil-Prime system implemented into actual Type I performance specifications?" The Air Force developmental engineers for the specific subsystems which make up a weapon system, e.g. the landing gear, environmental control system, the fuel system, etc., are responsible for writing the Mil-Prime specification for their specific subsystem. The engineers develop the specifications required for the RFP that is sent to individual contractors. The first five of the 60 planned Mil-Prime specifications have been written, and one of these specifications is investigated.

Answering the first research question requires interviewing a staff engineer who is responsible for all Mil-Prime specifications to ascertain whether or not the Mil-Prime specification for the functional area in question is representative of all Mil-Prime specifications. Assuming this criterion is met, the format and individual items of the Mil-Prime specification are evaluated according to a predetermined set of procedures described later.

The first of the 60 Mil-Prime specifications that has been completed is the landing gear specification. Because the Mil-Prime landing gear specification was completed before the Subsystem Requirements Document for the C-X was drafted, the Mil-Prime landing gear specification was used as a guide to prepare the landing gear specification for the C-X. The Mil-Prime landing gear specification was used as a guide rather than a requirement because Mil-Prime, which is still under development, has not been officially implemented. The C-X is the only aeronautical system, as of December 1980, that has had access to Mil-Prime documents that could be used as a guide in the preparation of its specification.

The Mil-Prime landing gear specification has been chosen as the aeronautical specification to be subject to rigorous comparative evaluation because: 1) it is the first Mil-Prime specification completed; 2) it has been used to describe an Air Force need to private industry; 3) it has been used as a sample by ASD engineers who are responsible for rewriting other Mil-Prime specifications; and 4) it has near-term

potential for inter-service use (11). Regarding this last point, precedent has already been set for the joint service, i.e. Army/Navy/Air Force, use of a Mil-Prime specification because a joint service Mil-Prime specification for parachutes has been approved (15).

A structured interview approach is used to test whether 1) the Mil-Prime specification for the C-X landing gear is representative of all Mil-Prime specifications, and 2) the C-X landing gear Mil-Prime specification follows the general outline for the Mil-Prime landing gear specification. The C-X landing gear engineers are asked to discuss the procedures that were used to develop the landing gear specification, and to describe how the specification was implemented into the C-X RFP (see Appendix B).

The second research question is: "What are some relevant differences between the new specification and the traditional Type I specification?" Once a representative Mil-Prime specification is found and its implementation described, a comparative evaluation between the representative Mil-Prime specification and its traditional counterpart is undertaken to answer the second research question.

The problems that have been encountered in the past with the traditional system counterparts of the Mil-Prime specifications have been described in Chapter I of this thesis, and the problems that ASD engineers expect to encounter with the application of the Mil-Prime concept are described in Chapter III. This latter set of expected problems are

documented as a result of a structured interview process.

The comparison of the Mil-Prime and traditional specifications addressed the following issues: 1) the potential flexibility and the simplicity of the Mil-Prime specification in comparison with the more traditional documents; and 2) the relationship between the performance requirements in section 3 of the military specifications versus the verification requirements in section 4.

Flexibility and simplicity can not be measured directly but indicants of these two properties are counted. These indicants include the number of pages, requirements, and reference documents in both the Mil-Prime and traditional specifications. These issues are described in greater detail in the succeeding paragraphs.

Interviewing and objective measures, each taken independently, do not confirm external validity, but using both methods together and checking for convergence of results certainly improves external validity considerations. The structured interviews allow the engineers to explain the differences, real and perceived, between the Mil-Prime and traditional specifications. The engineers who deal with the specific subsystem being evaluated are chosen because of their intimate knowledge of both types of specifications. Individual judgments and criticisms that result from the structured interviews are compared to data derived from counting the number of pages, requirements, and references to enable the researchers to make objective conclusions.

The flexibility of the Mil-Prime documents is indicated by counting and comparing the number of requirements in the Mil-Prime and traditional specifications. Flexibility is particularly important since it gives the competing contractors technically acceptable options that may result in lower costs. Dr. Puryear, who has written a guidebook for the development and preparation of specifications and standards for the Defense Materials Specifications and Standards Office, states that one of the main characteristics of a specification is that it becomes a requirements document (10: 13). The degree of detailed requirements stated in the specification impacts the contractor's flexibility of design, fabrication, and internal structure.

An example of the inflexibility of a requirement in a specification is the specification for clocks in aircraft. The increased technology of the digital clock has made time pieces less c stly, smaller, and more accurate than their traditional counterparts, but the Air Force has been unable to acquire these digital clocks for its aircraft since MIL-L-38207 requires that all clocks contain 15 jewels and three hands, one each for hours, minutes, and seconds.

The number of requirements to be counted does not explicitly demonstrate the flexibility or inflexibility of the Mil-Prime documents, but it provides an indicant of their flexibility; i.e. fewer requirements mean fewer constraints.

The simplicity of the Mil-Prime documents is indicated by counting both the number and the pages of the

referenced documents that levy requirements in both the Mil-Prime and the traditional specifications. This counting of documents, like the counting associated with the flexibility issue, does not explicitly support or refute the simplicity of the Mil-Prime documents, but it provides an indicant of their simplicity, i.e. clear understanding abhors referencing.

The assessment of relationships between the performance requirements in section 3 and the verification requirements in section 4 of the military specification places these relationships into three categories, as follows: absolute/direct, generally applicable, and vague/no correlation. The absolute/direct category is characterized by a close, logical, or consequential relationship. The vague/no correlation category is characterized by a relationship that is either not clearly defined or is not defined at all. The generally applicable category is characterized by a relationship that falls between the absolute/direct and vague correlation extremes. This thesis counts all the relationships in each category for each military specification. The requirements in each category for the Mil-Prime and traditional specifications are compared to determine if the Mil-Prime system provides the verifiable requirements that the traditional specifications system allegedly sometimes lacked. A key issue to bear in mind when assessing the relationship between section 3 and section 4 is that if section 4 does not specify verification for a section 3 requirement, then the contractor may not be contractually obligated to fulfill the section 3 requirement.

The engineers for the C-X landing gear are asked to compare the traditional and Mil-Prime landing gear specifications. The discussion of the traditional landing gear specifications is limited to the C-5 since this aircraft's landing gear shares commonality with the C-X aircraft, except for the kneeling system requirements in the C-5 which are not specified in the C-X (8). This commonality is based upon performance specifications, e.g. aircraft mission, landing speeds, etc.

This thesis traces and documents all references to the landing gear in the C-X specification, e.g. the subsystems requirements document, the general systems specifications, the structural specification, the hydraulic specification, the environmental systems specification, etc., and compares these references to the landing gear references in specifications for a similar military aircraft, the C-5.

The third research question is: "What is the flexibility and simplicity impact of the Mil-Prime documents resulting from these differences?" If the Mil-Prime specification is shown to offer more flexibility and simplicity, the advantages and disadvantages which impact the RFP are evaluated.

Mil-Prime specifications are written to avoid the detailed requirements of processes and material found in traditional specifications. Dimensions are only supplied where necessary to ensure placement and fit with related apparatus. There are certain claimed advantages and

disadvantages, as described below, in using specifications with a great amount of flexibility and simplicity.

The principle advantage claimed to the Government is that it is compatible with the "buy commercial" policy, so the manufacturer is not bound by arbitrary military standards with which he may be unacquainted. This curtails the expense of designing, acquiring, and specifying new machine tools, testing equipment and accompanying procedures. Another advantage is that potentially fewer changes must be made to a flexible specification than to a detailed specification when working in areas of rapid technological changes, such as the avionics industry. The third advantage is the possible greater number of contractors who will be financially eligible to compete if specifications are not restricted to any particular method or process. The fourth potential advantage is the Government's ability to benefit from a contractor's unique engineering efforts (10:46). With a great deal of latitude available for product design and manufacture, a contractor may find radically different ways to meet the performance requirements at substantial savings in cost while still providing a superior product. While little direct research has been done to verify these claims, their appeal is highly logical and they enjoy general support in the development community.

There are also disadvantages associated with more flexible specifications. One is the tremendous cost associated with developmental engineering. The Government may be required to help finance the research and development of the

subsystem if a contractor is to design an advanced technological product. A second disadvantage is the evaluation of different design types that competing contractors submit. This requires skillful and imaginative engineers and managers to evaluate the advantages and disadvantages of different designs. Along with this problem is the added time required to determine whether or not a contractor has complied with the specifications (10:47-48).

These advantages and disadvantages are evaluated through structured interviews with the engineers responsible for the specific subsystems in question. The engineers are given the opportunity to discuss and explain other advantages and disadvantages they feel are important, and the impact that these advantages and disadvantages have on the specifications of the aeronautical systems. The engineers responsible for the C-X landing gear specification and the staff engineers responsible for overall development of the Mil-Prime specifications are interviewed to explore the possible impacts that the previously mentioned advantages and disadvantages will have on future weapon system acquisitions.

Data Collection Plan

The first research question is: "How are the characteristics of the Mil-Prime system implemented into actual Type I performance specifications?" To answer this question, the Mil-Prime landing gear is acquired from the engineering staff of the Aeronautical Systems Division (ASD) at Wright-

Patterson AFB. Furthermore, actual Type I performance specifications which have used the Mil-Prime system are collected. Since the Mil-Prime landing gear specification for the C-X was available before the C-X specification was written, the C-X Systems Program Office (SPO) at Wright-Patterson AFB is the source of data for the actual Type I performance specification. The specific data collected from the C-X SPO is the landing gear specification for the C-X.

The second research question is: "What are some relevant differences between the new specification and the traditional Type I specification?" To answer this question requires not only the same Mil-Prime landing gear specification obtained for the first research question, but also a traditional landing gear specification from an aircraft system similar to the C-X, e.g. the C-5. The C-5 SPO at ASD is the source of the C-5 documents.

Furthermore, an answer with high validity to this second research question requires more than a comparison of the specification data in the Mil-Prime and traditional specifications. There also exists a need to interview the engineers who are responsible for writing the technical specifications in order to supplement the objective evidence with the judgment of the working-level experts. The engineers are located in ASD at Wright-Patterson AFB. The means by which these interviews are conducted is a structured interview procedure, using questions from the list in Appendix B entitled "Structured Interview Questions."

The third research question is: "What is the flexibility and simplicity impact of the Mil-Prime documents resulting from these differences?" To answer this question, the data collected to answer the second question is once again used. Specifically, measures of flexibility and simplicity result from both the counting and the interview processes. To accomplish this task, Appendix B includes questions relevant to all the research questions.

The kinds of data collected for this thesis and the research methods used for the evaluation of the data reflect the "pilot study" nature of this thesis. Mil-Prime is a new and untested system to which tens of thousands of manhours have already been dedicated. This thesis is the first known effort by independent observers to objectively evaluate Mil-Prime.

Data Analysis and Interpretation Plan

An analysis of the data available to answer the first research question requires a comparative evaluation of the Mil-Prime landing gear specification and the C-X landing gear specification. If the Mil-Prime guidance was followed, then each paragraph and subparagraph number in the C-X specification should be directly traceable to the same paragraph and subparagraph number in the Mil-Prime specification. If the C-X landing gear specification does not follow the Mil-Prime format either in whole or in part, then the engineer responsible for the C-X landing gear specification is interviewed

to determine why he did not follow the prescribed format, and his reasons are explored in detail.

An analysis of the data to answer the second research question requires, in part, a counting of requirements in both the Mil-Prime and traditional specifications. The counting procedure is as follows: 1) both researchers agree upon a consistent methodology to count requirements; 2) both researchers then independently count the requirements; 3) both researchers attempt to resolve their differences; and 4) if there are unresolved differences, the final count is an arithmetic average of both counts.

The consistent counting methodology used by both researchers attempts to differentiate between technical requirements and conditions. "Technical requirements" are defined in the definitions section of this thesis. Heuristically, requirements may be identified, in general, by the words "shall" or "will," except where "shall" or "will" clearly refer to a condition. "Conditions" are restriction of modifying factors on the technical requirements. For example, the first sentence in the following subparagraph is a condition, and the second and third sentences are separate requirements:

> 3.2.1.1.4 Pressure Release. The pressurization system shall have both normal and emergency provisions for release of pressure. The normal pressure release provisions shall be capable of dumping pressure without shutting off the pressurizing air source. The emergency pressure release provisions shall be capable of dumping pressure from maximum differential to ______ within ______ seconds with the pressurizing air source shut off automatically at initiation of dump.

Furthermore, since the use of "shall" and "will" is a heuristic, the presence of one or the other does not necessarily imply the existence of a requirement or a condition. Also the absence of "shall" or "will" does not imply that, in that instance, a requirement is not specified. For example, the following subparagraph is a requirement:

> 3.2.4 Engine Bleed Air. The engine bleed air system consists of the ducting and components that route bleed air from _______ to _______.

The use of the conjunction "and" poses the problem of determining whether a subparagraph constitutes one or more requirements. In general, the use of "and" implies that there are two requirements, unless the meaning of the sentence clearly reflects only one requirement. For example, the following subparagraph contains two requirements:

> 3.2.1.8.4 Jack Pad Configuration. All jack pads shall be in accordance with MS33559 and installed in accordance with MIL-STD-809.

"Exceptions" to a requirement are not counted as a requirement. For example, the following sentence is counted as one example:

> The landing gear arrangement and component design shall conform to the requirements of AFSCM 80-1, Volume I, except that the ground floatation requirements of Part B, Chapter 3, Section 4 shall not apply and tow lug or lugs may be in the horizontal or vertical plane.

"To Be Designated" (TBD) requirements items are counted as single requirements. Not only requirements are counted, but also numbers of pages, references, and source documents. A page is counted if there is writing on at least half the page. This methodology is chosen because it follows

the pattern of the Blackledge dissertation, and because any errors counting the traditional and Mil-Prime specifications will be counted consistently, which will allow the researchers to assume that these errors will cancel each other out.

The results of the structured interviews are compiled separately and then integrated with the analysis of the specification data. Differences of opinion among the engineers interviewed are reported and evaluated. Resolution of differences of opinion for the purpose of answering the second research question is considered unnecessary. The conclusions of this research effort make note of differences in the opinion of the experts interviewed (see Appendix C).

The interview questions have been structured, in part, to enable the researchers to understand the differences observed in the comparative analysis of the specification data. Conflicts between the conclusions drawn by the interviews are highlighted in the analysis.

An analysis of the data to answer the third research question is an extension of the analysis of the data to answer the second research question. The thrust of the second research question was to identify some differences between the Mil-Prime and traditional specifications. The thrust of the third research question is to identify the impact of these differences. To answer the third question , the researchers depend upon the expert opinions of the engineers interviewed. Conflicting opinions are reported. Resolution of differences of opinion for the purpose of answering the research question,

in this case, is considered necessary. The opinion of the experts interviewed are given equal weight. For the purpose of drawing conclusions, differences of opinion are resolved by the researchers as follows: the differences of opinion are clearly identified and placed, if possible, into categories; each category is defined and explained; the researchers then draw their own conclusions, and thoroughly document the rationale for these conclusions.

All results of the data analysis effort are categorized, and then summarized in narrative form. Conclusions are drawn only from the data; the conclusions are used to evaluate the validity of the Mil-Prime system. The analysis gathers together all the relevant data, from both the specification analysis and interview sources, and attempts to substantiate the answers to the research questions.

CHAPTER III

ANALYSIS AND FINDINGS

The Interviewees

Eight ASD engineers who have had some experience with Mil-Prime were interviewed. Some of the engineers actually wrote Mil-Prime specifications and handbooks; others used or supervised the use of these Mil-Prime documents to develop specifications for specific weapon systems, e.g. the C-X, LRCA (Long Range Combat Aircraft), and the engine for the NGT (Next Generation Trainer). Those engineers who were responsible for developing specifications for specific weapon systems used the Mil-Prime documents as a guide, rather than as a format that had to be rigorously followed. Mil-Prime is viewed by these engineers not as a rigid format that had to be followed, but as a concept that requires the specification of performance requirements in one document as opposed to the practice of referring the potential contractors to multiple military specifications. These engineers view Mil-Prime as a new means of communicating to a contractor the performance required for a piece of equipment; the specific design of that equipment, i.e. the Type II specification, is still the responsibility of the contractor.

How Mil-Prime Specifications Are Developed and Applied

The Mil-Prime landing gear specification was the first Mil-Prime specification completed, and it was distributed to all other Mil-Prime authors as an example to be followed. The Mil-Prime landing gear specification is considered by the engineers interviewed to be representative of other single-system Mil-Prime specifications. Single-system specifications, e.g. the landing gear, parachute systems, and fuel systems specifications, are differentiated from the multiple systems specifications, e.g. the structural integrity specification, which involve multiple engineering disciplines covering a wide range of hardware environments and technologies. Nevertheless, the multiple discipline specifications, according to the author of one of the multiple systems specifications, are expected to follow the same Mil-Prime format used in the Mil-Prime landing gear specification (3).

The Mil-Prime specifications were developed by reviewing all the relevant traditional specifications; deciding what parts of those specifications should be preserved; combining similar subsystems together, e.g. wheels, brakes, and tires; and then "cutting and pasting" until the Mil-Prime specifications emerged (15). Essentially, all the traditional specifications and standards were looked at with the intent of replacing them by 1) updating all the traditional requirements; 2) expressing the traditional requirements in terms of operational needs; and 3) ensuring that there were means of

verification to correspond with the specified requirements (3).

The C-X, which is the first weapon system to apply the Mil-Prime concept, incorporates a landing gear specification that was developed, according to the specification's author, using the Mil-Prime landing gear specification as a guide. Because many members of the C-X development group also participated in the cancelled AMST (Advanced Medium Short Takeoff and Landing Transport) program, the AMST landing gear specification was also used to develop the C-X landing gear specification. The AMST specification was developed using the Mil-Prime philosophy before the details of Mil-Prime were formulated. The AMST engineers were told to write a specification that minimized the use of reference specifications and that maximized the emphasis on performance (5). The engineers in the C-X program not only used the AMST specification as a baseline, but were also directed to use Mil-Prime documents for those areas of the aircraft where the Mil-Prime documents were available; where Mil-Prime documents were not available, i.e. if Mil-Prime documents were not yet developed for an area of the aircraft, the C-X engineers were directed to use the Mil-Prime approach (11). The C-X landing gear specification does not rigorously follow the Mil-Prime format because the performance-oriented AMST landing gear specification, which had already undergone rigorous review by both the internal ASD engineering committees and by defense contractors, was available and generally applicable for use by the C-X program (5).

The use of a Mil-Prime specification as a guide is not meant to imply that the engineers could choose to ignore Mil-Prime because it is generally not mandatory to follow a "guide." For example, the Mil-Prime landing gear specification, even though it is a guide to be used to develop landing gear specifications for specific aircraft, must be followed if the specific aircraft specification is to be approved by the ASD review committees (8). The major criterion, when choosing the words, is to tell the potential contractors what the engineer expects that aspect of the aircraft to do, but not to tell the potential contractors how to design that aspect of the aircraft.

The use of a Mil-Prime specification in conjunction with another aircraft specification, e.g. the AMST specification, is by no means unique. The landing gear specification for the LRCA was developed using the Mil-Prime, C-X, B-1, and FB-111 landing gear specifications, along with the LRCA statement of work, and information from the "problems" file of past landing gear problems. Some of the "problems," incidentally, had already been documented in the original version of the Mil-Prime landing gear handbook (8). The LRCA landing gear specification became available to the researchers late in the course of this thesis effort, but was not used because the LRCA landing gear specification was more of a blending of the actual existing B-1 and FB-111 landing gear specification than a new specification to which the contractors were expected to respond. The researchers noted that the LRCA landing gear

specification does rigorously follow the paragraph and sub-paragraph numbering system in the Mil-Prime landing gear specification, and in that respect is probably more representative of future Mil-Prime landing gear specifications than the C-X specification, which takes more liberties with the Mil-Prime format. But the C-X landing gear specification, because of its performance orientation, and because it is a complete document that references few other specifications (see the section of this chapter entitled "Objective Measures of Mil-Prime), is certainly representative of the other Mil-Prime specifications that are being developed.

A summary of the specification writing process using Mil-Prime is depicted in Fig. 2.

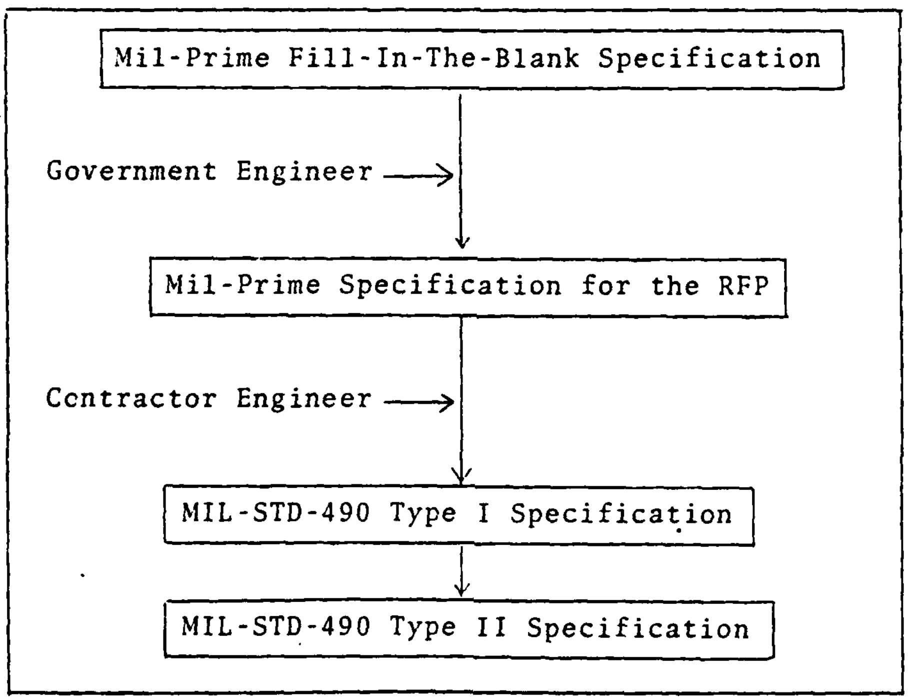

Fig 2. The Specification-Writing Process Using Mil-Prime

A Government engineer would use a Mil-Prime "fill-in-the-blank" specification to develop a Mil-Prime specification for a specific system or subsystem of an aircraft. This latter specification would be incorporated into the request for proposal (RFP). Potential contractors may respond to the RFP with their own Type I specification in the MIL-STD-490 format, or they may accept the Government's specification that was incorporated into the RFP as the final Type I specification. The contractor who wins the contract award would then develop the Type II specification in the MIL-STD-490 format (21).

A Comparison of the Traditional and Mil-Prime Systems

The engineers interviewed more readily identified differences between the traditional and Mil-Prime systems than they identified similarities. Yet the similarities that they identified are significant. The total approach to specification requirements is similar. Mil-Prime is essentially a rewrite of traditional specifications using the same six section format, and in many cases using the exact wording from the traditional specifications. The same performance requirements exist with both systems, except Mil-Prime expresses these requirements more explicitly. The baseline verification section (section 4) is essentially the same for the two systems, but Mil-Prime more rigorously ensures that verification of each requirement is specified. For example, the MIL-B-8584 problem, cited in Chapter I, in which an

aircraft parking brake was required to hold an aircraft on an 18° slope, but no means of verifying this requirement was specified, would not be a problem under Mil-Prime because Mil-Prime's format ensures that verification of each requirement is specified in terms of performance.

A comparative analysis of section 3 (requirements) and section 4 (verification) in the C-X and C-5 landing gear specification is summarized in Fig. 3. This comparative analysis reveals that there is a direct/absolute correlation between all subparagraphs in section 3 of the C-X specification with all subparagraphs in section 4 of the same specification. But the correlation for the C-5 was significantly different from the C-X. Of the 16 major subparagraphs for the C-5, numbered 3.3.1.7 to 3.3.1.7.9 in specification No. CP40002-2B, ten subparagraphs had absolute/direct correlation; and one subparagraph, number 3.3.1.7.5, had a generally applicable relationship with corresponding paragraphs in section 4. More significantly, five of the subparagraphs did not have any corresponding paragraphs in section 4. This indicates that there was not any contractually specified means of verifying, for example, the testing of the landing gear warning horn (paragraph 3.3.1.7.1.3), or the operation of the emergency brake (paragraph 3.3.1.7.4). The verification requirements in the Mil-Prime landing gear specification incorporate a numbering system which corresponds to that used in section 3 so that the verification requirement relates more directly to its performance requirement.

Number of Requirements with a:	C-X	C-5
direct/absolute correlation	79	10
generally applicable correlation	0	1
vague/no correlation	0	5
Total	79	16

Fig 3. Correlation Between Section 3 and Section 4

The differences identified by the engineers between the traditional and Mil-Prime systems are more readily identifiable. The traditional specifications incorporate lessons learned with the specifications themselves by specifying requirements that address previous problems. The Mil-Prime specifications are exclusively performance oriented, with references, procedures, and lessons learned delegated to the accompanying Mil-Prime handbook.

Several engineers stated that the concept of tailoring specifications highlights a significant difference between Mil-Prime and the traditional specifications. The traditional specification could be tailored by deleting aspects of the specifications that were judged not to be applicable to a specific weapon system; the Mil-Prime specifications are designed from the outset for a specific weapon system. In the past, the contractors would, in general, anticipate what the Government's specification in the RFP was going to say since the same specifications were referenced over and over again. With Mil-Prime, the contractors apparently will have to spend significantly more time with the Government engineers before

issuance of the request for proposal to have as complete an understanding of the Air Force requirement; otherwise, the contractor will have little idea how the Government engineer is going to fill in the blanks, i.e. tailor the Mil-Prime specification to a specific weapon system. The Mil-Prime system may lead contractors to question many filled-in blanks to see if the Government is serious about those requirements, whereas in the past contractors were hesitant to question specifications which had been used over and over again. This expected questioning of the tailoring process by contractors should potentially result in a reduction in the number of requirements to an absolute minimum, which would allow the contractors maximum flexibility to design a weapon system that meets the essential requirements at the minimum cost.

The expected questioning of the tailoring process by contractors should, according to several of the engineers interviewed, also encourage Government engineers to do their homework well before issuing the specification to industry. In the past, Government engineers depended on the traditional specification to specify the requirements and to cover up for an engineer's lack of knowledge concerning certain areas of a specification, by referencing every specification dealing with the system or subsystem for which the engineer was responsible. With Mil-Prime, the Government engineer must address each discipline when he specifies the requirements; no longer can he depend on referencing specifications and postponing learning the details of those specifications until

the engineer reads the contractors' proposals. Mil-Prime thus requires more front-end effort by Government engineers; Mil-Prime essentially provides a checklist guide for the Government engineer's front-end efforts.

The rewriting of the specifications into the Mil-Prime format will bring about the deletion of many outdated and undesirable requirements and specifications. For example, a rewriting of MIL-L-38207, which was cited in Chapter I as requiring 15 jewels in the clock on an aircraft instrument panel, would specify performance characteristics rather than design characteristics for a clock, which would, in turn, allow the use of the more modern digital clocks. By cleansing the system specifications of many unnecessary design details and design requirements, both the contractor and Government purchasing groups eliminate unnecessary manhours, paperwork, and cost to justify non-compliance to specifications which are not applicable.

Another factor favoring the Mil-Prime system, according to several of the engineers, is its exclusive performance orientation. Unlike the traditional specifications, the Mil-Prime specifications get away from driving a contractor to a specific design. A contractor will have greater latitude to meet these performance requirements by balancing cost, weight, and performance characteristics in an optimal fashion than he would if constrained by a design limitation. Significantly, the statement of the requirements in terms of operational needs in the Mil-Prime specification should eliminate some of

the cost drivers in the traditional specifications by allowing the contractors more flexibility of design. The contractor's innovations will not be stifled by a fear of going against a military specification and being accused of being nonresponsive.

The exclusive performance orientation which Mil-Prime emphasizes could bring about problems in verification, according to one engineer. For example, in the case of a radio which is required to transmit for 100 miles, many variables will influence the performance of the radio, such as atmospheric conditions, terrain, and personnel testing the equipment. In a traditional specification, a design requirement would usually be specified which required that radio to broadcast with an output of 30 watts, for example, which is very simple for an engineer to verify. Verification of the 100-mile transmission requirement under variable conditions will be more difficult to accomplish (11).

Another aspect causing concern among some of the engineers is that more discussion is required between the ASD engineers and the operating or using command of what is really needed prior to the issuance of the request for proposal. Most using commands are not tuned to supplying engineers with functional design. For example, project personnel of the using command talk of combat turn radius, while engineers speak of degrees of bank at a given mach number.

The Mil-Prime emphasis on performance improves communication between the engineer and the using command. When

the engineer used the traditional specification, he wrote in a language that the user did not understand, e.g. he specified what the thrust of the engine would be, but did not specify what the impact of the level of thrust would be on operational requirements. When the engineer uses Mil-Prime, discussion with the using command is enhanced because the engineer is writing more in the language that the user understands, and the user is better able to communicate his needs with the engineer.

The traditional specification approach called for each subsystem to be designed and laboratory tested as an entity within itself prior to being mated with the other subsystems to comprise the entire system. However, in some cases, the sum of the whole does not equal the sum of its parts. For example, the F-15's tires wore unacceptably on their edges after approximately nine landings because of poor integration with the landing gear. The traditional specifications called for tires and landing gear separately. Both subsystems met the laboratory verification requirements, but were not required to be mated and tested. The prime contractor was not held responsible to ensure that the landing gear and tires worked well together. Neither the tire nor landing gear contractors could be held responsible for the unacceptable wear of the tires since both contractors successfully completed their respective laboratory tests and design requirements.

A Mil-Prime specification, on the other hand, will call for a landing gear capable of allowing, for example, at

least 50 landings per tire. If the aircraft did not satisfy this requirement, then the prime contractor would clearly be responsible for correcting the landing gear's design problem (15). This means of designing weapon systems generally transfers the focus on acceptance of the weapon system to the total weapon system performance rather than the laboratory performance of the individual subsystems.

Mil-Prime's handbook provides the corporate memory, through its lessons learned, which should prevent problems like that with the F-15 landing gear from occurring. The handbook must continuously be updated to maintain its currency so that no innovative designs are overlooked. An example would be the carbon brakes used on landing gears. The first couple generations of the carbon brakes were plagued with problems and were inferior to the standard steel brakes. Succeeding generations of the carbon brake overcame the problems encountered, and are now as good if not better than the steel brakes. If the handbook were not kept current with the advances made with the carbon brakes, engineers who were not intimately familiar with the material would rate the design specification of a contractor who proposes the use of carbon brakes as inferior (8).

Mil-Prime, according to some of the engineers interviewed, will aid in eliminating unnecessary cost drivers. For example, the maintainability requirements in a traditional engine specification would not differentiate between an aircraft or a missile, yet the missile's engine would not need

to be maintainable since it is not reusable. Mil-Prime, through the tailoring process, would correct this problem. Another example of a cost driver would be costly testing required by a traditional specification which was not important to the operation of an aircraft.

A new system, such as Mil-Prime, could not be expected to be implemented without causing some problems. The Government loses some control over the contractors because the contractors now have more design discretion. The details of each aircraft subsystem, which were previously controlled by the Government engineer, are now a contractor's responsibility. It is possible that problems could develop as a result of not following the dictates of the traditional specifications. On the other hand, according to some of the engineers interviewed, the transfer of emphasis from accepting subsystems in a laboratory environment to acceptance of a total aircraft basis should cause a lessening of costly engineering change proposals that were necessary because problems did not surface in the laboratory, but did surface during aircraft performance.

Mil-Prime, according to the engineers interviewed, could also make the working environment more intense for the Government engineer because he will have to pay more attention to detail before the specification is released to the contractors. On the other hand, paying more attention at the front-end should result in a better product down the road. Of course, if engineering manpower is constrained and not enough

time is available to spend at the front-end, problems could develop as a result. Then again, if the Government must depend on new, inexperienced engineers, engineers who could not reasonably be expected to develop adequate specifications using the multitude of traditional specifications, Mil-Prime will enable these engineers to develop adequate specifications by following the Mil-Prime fill-in-the-blank specification checklist. New or inexperienced engineers may run the risk, when using the Mil-Prime specification, of omitting necessary requirements which, some engineers fear, could require expensive change proposals if the omissions are not found prior to full-scale development. This was not a problem when the traditional specifications were used, since an engineer, when in doubt about a requirement or a group of requirements, could always reference the appropriate military specifications and be assured that he had covered the requirement.

Mil-Prime's ease of implementation, i.e. its simplicity and its flexibility, versus that of the traditional specification system is an important issue. Most of the engineers interviewed believe that Mil-Prime will be a simpler system from the Government manager's point of view, but more difficult from the lower level project engineer's point of view. This is true because the Government's level of control is higher, i.e. at the aircraft performance level rather than at the subsystem level, so that there should be a greater ease of implementation of the essential requirements. For example, monitoring qualification testing at the aircraft level will

certainly be less of a burden for the Government than monitoring qualification testing at all vendor levels. Furthermore, keeping the Mil-Prime handbooks up to date, which may be a challenging task because of manpower constraints, will certainly be an easier task, according to some of the engineers interviewed, for the ASD engineering community as a whole because it is easier to update approximately 60 Mil-Prime specification handbooks than several thousand traditional specifications.

On the other hand, Mil-Prime will be a learning process that will necessitate a better understanding between ASD and the contractor community regarding the identification of the requirements, which will impact the ease of implementing Mil-Prime. The Government and the contractor engineers who will be working directly with the various specifications may find Mil-Prime more difficult to implement than the traditional specifications.

From the Government engineer's point of view, it was claimed that there will be the need to pay more attention to the initial requirements that are sent to the contractors. The traditional specifications could be readily implemented in one paragraph of referenced specifications, while with Mil-Prime a Government engineer must be aware of every requirement he is specifying. No longer will the Government engineer be able to rely on the multitude of military specifications to cover for his lack of knowledge or preparation.

The contractor's engineers, again according to some

of the Government engineers interviewed, will find that the unrestricted freedom of design makes their design decisions much more difficult because of the number of options available to them. When the traditional specifications were used, a design requirement was usually specified which explained to the contractor's engineer how the subsystem was to be designed. With Mil-Prime, the contractor's engineers will have to design their own subsystems.

Mil-Prime's flexibility appears to be less questionable with the engineers interviewed than its simplicity. Mil-Prime presents the opportunity for the contractors to enter into discussions with Government engineers as to what approach is best for a specific aircraft. In the past, these discussions were discouraged because the Government engineer depended on the "locked-in-concrete" traditional specifications to establish the requirements.

Mil-Prime, as some of the engineers believe, is not as absolute as the traditional specifications as to what should be done and what should not. The traditional specifications still exist to aid the thought process of the contractors, but the contractors now may use many of these traditional specifications as no more than guides. The traditional specifications, by incorporating requirements to prevent past mistakes from repeating themselves, became conservative and inflexible. Mil-Prime allows the contractors the flexibility to quote the best design to fulfill the requirement; the Government then determines if the contractors' designs are adequate, and

determines the best design. Mil-Prime allows the Government engineer the flexibility to decide what is important and what is not, which is a flexibility that the incorporation of referenced traditional specifications never allowed. More importantly, Mil-Prime's orientation towards operational requirements, and its flexibility in allowing the contractor to design a system that best meets these requirements, provides to the using command, the ultimate customer, an aircraft that meets the operational need.

Acceptance of Mil-Prime

Because Mil-Prime represents a change to the traditional way of doing business at ASD, one would expect both acceptance of and resistance to the change. Defense contractors have been giving positive feedback, the engineers say, regarding Mil-Prime. The Aeronautical Industries Association, the Electronics Industries Association, and the Society of Automotive Engineers have reviewed specific aspects of Mil-Prime and have indicated that Mil-Prime is a change for the better (21). Some criticism of Mil-Prime to date from industry has been related to the detailed descriptions of the lessons learned in the Mil-Prime handbooks; apparently some contractors are sensitive that their past mistakes are being published in a Government document (15). Other criticism from industry seems to relate to a "not invented here" attitude, which causes resistance that should dissipate after contractors recognize the new flexibility that Mil-Prime will give

them. This new flexibility centers upon the capability given to contractors by Mil-Prime to help write a Type I performance specification that is tailored to the needs of a specific weapon system as opposed to the practice of detailing a list of exceptions to referenced traditional specifications. There is also a feeling, according to some of the Government engineers interviewed, that Mil-Prime will not be well received by the working level engineers in contractor organizations. Mil-Prime may make these engineers uneasy because they are used to having the Air Force tell them what to do and then applying what the Air Force says to their design; Mil-Prime requires these engineers to do more thinking, to exert more control, and to be more original, all of which is a change from the traditional practices.

The ASD engineering community, as represented by the engineers interviewed, also has been giving positive feedback regarding Mil-Prime. Initial impressions were characterized by skepticism, apprehension, and reluctance, partly because many Government engineers were used to detailed control over technical specifications, and they did not want to relinquish this control, and partly because some Government engineers relied upon the traditional specifications as a "security blanket" that they could fall back upon. But the attitude of many ASD engineers seems to have changed as they listened to advocates of Mil-Prime within the ASD engineering community, as they help develop these Mil-Prime products, as they understand that the system is workable and that it is here to stay,

that it does not tie their hands, and that manpower constraints will limit their future ability "to get their hands dirty" in the details of designing a new system.

Objective Measures of Mil-Prime

This evaluation of Mil-Prime in comparison with the traditional specification system attempts to find and measure objective evidence regarding the simplicity and flexibility of both the new and the traditional specification-writing system. Central to the evaluation of objective evidence is the isolation of requirements so that these requirements may be counted. Requirements are performance parameters which are found in section 3 of the Mil-Prime and traditional specifications. Any function for which the using command needs a piece of hardware to perform is a requirement. If one piece of necessary hardware cannot be used without a second piece, that second piece is also a requirement. If requirements must interface with one another, e.g. the requirement for aircraft strength, then the interface is also a requirement. Anything that drives the design, or is derived from the using command's Statement of Operational Need (SON) is a requirement. The Government engineer's role is to act as a middleman, putting words into paragraphs to translate the SON into a requirements document that will communicate operational needs to the contractor so that the contractor may develop the design.

Requirements are generally identified by the word "shall." The words "should" and "goal" identify sentences

that are not requirements. Sentences in section 3 of the specifications that do not use "shall," "should," or "goal" are generally, but not necessarily, requirements. A clear, universal definition of what a requirement is and what is not a requirement is, however, not of high importance. A reader of this thesis may develop his own counting methodology and still should develop similar findings. What is important is the consistency in counting the requirements in both the Mil-Prime and traditional specifications. Because of this consistency, which is explained in Chapter II's written methodology, any incorrect identification of requirements in one specification should be counted incorrectly in the other specification; any definitional errors should then cancel each other out, while obvious deviations were watched for.

Indicants of simplicity and flexibility in the Mil-Prime and traditional specifications were counted. Simplicity could perhaps best be indicated objectively by counting the number of subsequent contract problems associated with a chosen specification-writing practice, but this data is neither historically available nor is it practical. Simplicity in specifications might also be indicated by the use of easier to understand language, or a more specific choice of words, e.g. avoiding the overuse of phrases such as "in accordance with" or "not limited by," but such phrases do not appear to go to the heart of the meaning of simplicity. The premise of simplicity is that if a requirement is specific and well-defined, then it is clear what the requirement is, it is clear

how to verify the requirement, the contractor knows how to bid, and the Government engineer knows how to evaluate the proposal. Simplicity is measured by counting pages of referenced requirements.

Results of the counting of the referenced documents in the C-5 and C-X specifications are as follows. The section of the C-5 specification that specifically addresses the landing gear requirement, i.e. paragraphs 3.3.1.7 through 3.3.1.7.9 is seven pages and incorporates eight documents by reference, including 180 total pages of required referenced specifications, and 542 pages of an Air Force Systems Command (AFSC) manual. These documents and the associated page count are:

Document		Page Count
AFSCM 80-1, Volume 1		542
MIL-P-5518		17
MIL-T-5041		25
MIL-W-5013		40
MIL-B-8584		12
MIL-S-8812		21
MIL-H-5440		40
MIL-S-8552		25
	Total	722

In addition, the C-5 specification includes 35 pages of other landing gear-related requirements, including "landing conditions" and "ground operations conditions," in paragraphs 3.1.1.1.11, 3.4.1.3 through 3.4.11.11, and 3.4.12 through 3.4.12.12.3.

In contrast, the section of the C-X specification

that specifically addresses the landing gear requirement, i.e. paragraphs 3.1 through 3.2.1.9.2 entitled "Landing Gear System" of the C-X subsystem requirements document, is ten pages and incorporates three documents by reference, which total nine pages of requires references, including MS33559, a military standard/drawing, which is counted as one page:

Document	Page Count
MIL-STD-805A	2
MIL-STD-809	6
MS33559	1
Total	9

Significantly, the C-X specification does not include any other obvious landing gear or landing gear-related requirements. While it is tempting to credit Mil-Prime with this significant finding, the Government engineer who authored the C-X landing gear specification informed the researchers that the C-X does not have multiple sections defining landing gear requirements because the same Government engineers who worked on the C-5 landing gear also developed the C-X landing gear specification. These engineers learned from their C-5 experience, and applied that learning, including the necessity to consolidate multiple sections, to the C-X (5). Significantly, with Mil-Prime, the lessons learned through the practical experience of these C-5 engineers will be retained in the Mil-Prime handbook. If not for the existence of the Mil-Prime handbook, the lessons learned might have been lost to successive generations of engineers (21).

Flexibility is somewhat easier to measure objectively than simplicity. As with simplicity, the fewer the number of required referenced documents, the more flexibility a prime contractor has to design a weapon system that best meets the performance need. The Government engineer also has more flexibility because he can pick and choose the appropriate requirements, whereas with the traditional system he was limited to making exceptions to the established referenced specifications.

The number of requirements in the C-5 and C-X specifications were counted to help indicate the relative flexibility of these documents. Surprisingly, the landing gear portion of the C-5 specification, paragraphs 3.3.1.7 through 3.3.1.7.9, even with its unique kneeling system requirements, had less requirements, a total of 76, than the C-X landing gear specification, which had 151 requirements. An analysis of this finding readily revealed the reason for this discrepancy. The C-X landing gear specification references three other documents, which have a total of nine pages. The C-5 landing gear specification not only references other documents which have a total of 722 pages, 713 more pages than those referenced by the C-X specification, it also includes 35 pages of landing gear-related requirements that are not consolidated with the landing gear section of the C-5 specification. The basic C-5 specification is shorter, even though its subparagraphs are much more lengthy, but it includes, because of the references and other associated pages, many more requirements. The basic C-X Mil-Prime specification appears to have more

requirements, but in fact, because it is compact and because it stands on its own without the extensive use of references, it has significantly less requirements than the C-5 traditional specification.

A summary of the objective measures used to compare the C-5 traditional specification with the C-X Mil-Prime appears in Fig. 4.

Aircraft	C-5	C-X
Number of pages in the landing gear section of the specification	7	10
Number of subparagraphs in the landing gear section of the specification	10	79
Number of requirements in the landing gear section of the specification	76	151
Number of pages addressing other landing gear-related requirements	35	0
Number of referenced documents in the landing gear section of the specification	8	3
Number of pages of documents referenced in the landing gear section of the specification	722	9
Total number of pages in the specification that address or reference landing gear requirements	764	19

Fig 4. A Summary of the Objective Results

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The conclusions in this chapter address and expand upon the research questions which are listed at the end of Chapter I. A reader of this thesis who wants to understand the essence of the findings of the researchers without reading the entire thesis should read the section of Chapter III entitled "A Comparison of the Traditional and Mil-Prime Systems."

To date, an actual Type I performance specification has not been developed solely from a Mil-Prime document. As stated in Chapter I, only five Mil-Prime specifications have been written as of October 1980. Of these five, the landing gear specification was the first to be completed. The ASD engineer who directed the writing of the Mil-Prime landing gear specification indicated that the Mil-Prime landing gear specification has been and is currently being used as an example to be followed in the writing of all other Mil-Prime specifications. This engineer added that the Mil-Prime landing gear specification is only a guide, and many other Mil-Prime authors are adding their own individual ideas to their documents, while still keeping the basic Mil-Prime format (15).

This same engineer is also a member of the reviewing

committee which attempts to standardize and assist in the writing of other Mil-Prime specifications (15). Authors of other Mil-Prime specifications interviewed in this thesis effort have acknowledged that their documents closely resemble that of the Mil-Prime landing gear document, and some have had their specifications before the reviewing committee several times to ensure conformance with the committee's direction.

As far as the C-X landing gear specification is concerned, after an examination of the C-X landing gear specification and the Mil-Prime landing gear specification, and interviews with the principal authors of the C-X landing gear specification, the researchers concluded that the C-X landing gear specification follows the general outline for the Mil-Prime landing gear specification. There is less evidence that the C-X landing gear specification is representative of all Mil-Prime specifications because so few other Mil-Prime specifications have been completed, but since the Mil-Prime landing gear specification is being used as an example for other Mil-Prime efforts, it is believed that the C-X landing gear will be representative of a majority of the completed Mil-Prime specifications.

Furthermore, the principal author of the C-X landing Gear specification explained that the AMST landing gear specification, the basis for the C-X landing gear, followed the same philosophy as the Mil-Prime concept, which was being formulated at about the same time. That philosophy includes

making the specification solely performance oriented. Since the C-X landing gear specification was written, it has gone through many iterations, and with each iteration its format was written closer to that of the Mil-Prime landing gear specification (5).

The relevant differences between the Mil-Prime specification and the traditional specification, analyzed in Chapter III, are summarized here. The reader is cautioned especially when reviewing results of the objective data, there is a direct correlation between claimed flexibility and the numbers of requirements and between simplicity and the number of pages of referenced documents. The arguments on each will tend to merge as this rationale is developed, as one must recognize that referenced pages, in fact, will include number of requirements. The interviews with the engineers support the notion that the Mil-Prime system is more flexible than the traditional system, whereas, the objective data, on its face, appears to refute the engineer's beliefs. One of the surprising differences between the two systems, which is brought out by the counting of requirements in both the traditional and Mil-Prime systems, is the greater number of requirements in the C-X landing gear specification. As the findings bring out, however, this is caused primarily by the incorporation into the C-X specification of requirements included in referenced documents of the C-5 specification. It is also caused by the additional 35 pages of landing gear-related requirements that are spread through other sections of the C-5 specification--an untidy way

of specifying anything. The wide disparity in the combined total number of pages in the basic and referenced specifications that address landing gear requirements (764 vs 19) lead the researchers to believe that the C-X landing gear specification, and therefore the Mil-Prime system, has less total requirements, and is therefore the more flexible of the two systems.

The objective evidence on referenced pages seems to indicate that the C-X landing gear specification is simpler to follow since most of the requirements are stated in the landing gear specification itself rather than spread out over various referenced documents as in the case of the C-5. The correlation between section 3 and section 4 shows a much greater correlation between the C-X requirements and verification sections that the corresponding sections of the C-5. The high correlation between sections 3 and 4 of the C-X landing gear specification also seems to indicate a more direct, and hence simpler, document for the contractor to evaluate than that of the C-5.

But even though the objective data would make it appear that Mil-Prime is simpler, in some ways the Mil-Prime system, as explained by the interviewees, is more difficult. For example, with Mil-Prime the contractors will have to spend significantly more time with the Government engineers before the issuance of the RFP to have as complete an understanding of the Air Force requirement as the contractor had under the traditional specification-writing system before the RFP was

issued. Otherwise, the contractor will have little idea how the Government engineer is going to tailor the Mil-Prime specification to the specific weapon system. This increased front-end effort, however, which is required by the Mil-Prime process, while making the engineer's job more difficult initially, should give the contractor more flexibility to design a weapon system that meets the essential requirements at the minimum cost. The increased front-end effort will also encourage Government engineers to do their homework well before issuing the specification to industry, i.e. instead of depending on the traditional specifications to specify the requirements, the Government engineer must understand and address each discipline when he develops the specification that will be incorporated into the request for proposal. The engineers are thus investing more effort in the front-end of the contract to truly tailor requirements instead of paring standard documents which passed for tailoring in the past.

The impact of Mil-Prime will initially be seen in the increased interaction of the contractors, the ASD engineering community, and the using command representatives. There will be more emphasis on designing more precisely the weapon system desired by the using command. The Government engineers will find that a greater amount of time will be required to tailor the specifications to a specific weapon system.

The increased interaction between the main participants in a weapon system's design and the added emphasis by

the Government engineer in writing the performance requirements should eliminate the time, work, and cost that a contractor would expend in trying to justify the exclusion of many items that were previously and unnecessarily included in the traditional specifications. Since all parties involved would initially have a better understanding of what is desired, it should follow that fewer engineering change proposals would be required, which could significantly lower the cost of a weapon system.

The contractor will gain more control and responsibility over a weapon system design, which potentially will give him greater latitude to meet the performance requirements by balancing cost, weight, and performance. The contractor will find that this greater latitude, however, is a two-way street because he will be more responsible for the success or failure of his design since the Government engineer will no longer specify specific aspects of the design.

Recommendations

This thesis provides an evaluation of Mil-Prime in Mil-Prime's infancy. There will be many more opportunities, as Mil-Prime matures and is more widely used within ASD to develop new weapon systems, to compare Mil-Prime with the traditional specification system that it replaces. These opportunities should be seized by future research teams not only as a means to objectively document the success or failure of the Mil-Prime concept, but also to provide the evidence,

if Mil-Prime is successful, to convert the specifications practices of the other branches of the DoD and the Government to the Mil-Prime approach.

This thesis follows Mil-Prime's implementation into the RFP stage of a major production program, the C-X. The thesis makes note that Mil-Prime is also being applied in other programs, e.g. LRCA. Certainly a future research team should follow the development of Mil-Prime through the weapon system acquisition cycle, including deployment into the operational environment. Areas of interest, for example, would be the discussion provoked on contractual negotiations because of the Mil-Prime specifications, the problems caused in development and production by the Mil-Prime approach, and an evaluation of Mil-Prime's impact on the final product after deployment.

Another area of interest for a future research team would be an investigation into how commercial contractors specify their requirements to their subcontractors. For example, one might compare a commercial contractor's landing gear specification with Mil-Prime to determine either if commercial contractors are "Mil-Priming" their subcontractors, or if they are using a system of referencing their own specifications for mandatory use by their subcontractors, a system analogous to the traditional military specification system. Such an analysis would be enlightening if it determines that major defense prime contractors are restricting the design discretion of their subcontractors by specifying design

requirements using standardized specifications, similar to the traditional military specifications, because the impact on subcontractor costs due to the lack of design flexibility would be analogous to the impact on prime contractor costs to the Government due to the lack of design flexibility in the traditional specification system.

Particular attention in future studies should be directed to aspects of Mil-Prime which some of the interviewed engineers identified as aspects needing improvement. One aspect is the Mil-Prime handbook, which must be regularly updated at least once per year, to reflect current "lessons learned." Higher work priorities, according to several of the engineers interviewed, may lead to neglect of this updating process. Furthermore, the handbooks may be too comprehensive, e.g. the combining of lessons learned for fighters, bombers, and cargo aircraft in one specification may be inappropriate. As of April 1981, the ASD Deputy for Engineering (ASD/EN) is requiring that the results of all aircraft accident reports be incorporated into the appropriate handbooks. In the future, ASD/EN can be expected to establish procedures to ensure that the handbooks are regularly updated (21).

A second aspect of Mil-Prime that may need improvement is the verification system, i.e. section 4 of the Mil-Prime specifications. In the haste to develop Mil-Prime documents, the tests specified to check compliance with the section 3 requirements may be unrealistic or impractical.

A third aspect is the appropriateness of writing a

Mil-Prime performance specification for existing aircraft. For example, the LRCA landing gear engineer wrote, in the Mil-Prime format, a landing gear specification that essentially addressed the performance characteristics of the existing B-1 and FB-111 landing gears, because one or both of these aircraft, as of April 1981, will be chosen as the Air Force's new manned bomber (8). Perhaps an acceptance of the existing specifications would have been more appropriate in this case than writing a new specification. Of course, if the selected LRCA is significantly different from either the present B-1 or FB-111, e.g. if a B-1 configuration half the weight of the current B-1 is selected, then a new landing gear, and a new landing gear specification, would be required (21).

A fourth aspect is the potential for subsystem engineers to specify testing of the aircraft in different configurations. Such specifications would require a more extensive flight test program than if, for example, one or several test configurations were made mandatory by an overall Mil-Prime specification at the level of the system specification or the air vehicle specification. Since Mil-Prime is essentially a "bottom-up" concept, i.e. many separate Mil-Prime specifications are placed together to form the overall system and air vehicle performance specifications, an overall, i.e. "top-down," Mil-Prime specification that would place limits on the Mil-Prime subsystem requirements does not exist. Such an overall guiding specification, i.e. a Mil-Prime system specification, may have potential.

Future research teams also may use the findings in Chapter III of this thesis to develop a Mil-Prime questionnaire that could be sent to a large sample of ASD and defense contractor engineers. The purpose of a large sample would be to provide the basis for a more rigorous review of the impact of Mil-Prime across the breadth of the ASD engineering community as opposed to the more limited sample of engineers used in this thesis. The questions in this future questionnaire would certainly use most of those listed in Appendix B as a base, but should also address other issues uncovered by this thesis, e.g. the differences in format and approach among the many and varied Mil-Prime specifications; the impact of these differences on the design of the total aircraft; and the aspects of Mil-Prime, cited above, which according to the engineers interviewed need improvement.

Finally, it is the hypothesis of the researchers that the most significant cost driver in defense contracting is the specifications. The researchers would have liked to find some direct link between the statement of requirements and the subsequent contract costs, but data were not available to support this hypothesis. It would be a significant accomplishment if a future research team could devise a data collection system that would establish this link. Perhaps the weapon systems using Mil-Prime will, over their life cycle, surface this data.

APPENDIX A

THE MAJOR SYSTEM ACQUISITION CYCLE

The major system acquisition cycle, according to the Office of Federal Procurement Policy, consists of seven phases, as follows, each of which is described below: 1) mission analysis; 2) evaluation and reconciliation of needs in context of agency mission, resources, and priorities; 3) exploration of alternative systems; 4) competitive demonstrations; 5) full-scale development, test, and evaluation; 6) production; and 7) deployment and operation (8).

1. Mission Analysis: A continuing analysis by a federal agency of current and forecasted mission capabilities, technological opportunities, overall priorities, and resources that are involved for meeting the national needs that are the responsibility of that agency.

2. Evaluation and Reconciliation of Needs in Context of Agency Mission, Resources, and Priorities: When the mission analysis identifies a deficiency in existing agency capabilities or an opportunity to establish new capabilities in response to a technologically feasible opportunity, this is formally set forth in a mission need statement. The mission need statement includes the mission purpose, capability, agency components involved, time constraints, value or worth of meeting the need, relative priority, and operating constraints, and is not to be expressed in terms of equipment or other means which might satisfy the need. Approval of a DoD mission need statement by the Secretary of Defense represents

milestone zero in the Defense Systems Acquisition Review Council (DSARC) cycle.

3. Exploration of Alternative Systems (the Conceptual Phase): Approval of the mission need formally starts the major system acquisition process by granting authority to explore alternative system design concepts. During this phase, a program manager is designated and an acquisition strategy is developed. One of the key steps in the implementation of the acquisition strategy is the solicitation to industry in terms of mission need. The responses from industry are then evaluated, and the most promising system design concepts are selected for further exploration. Parallel short-term contracts may be let for those concepts selected for further exploration.

4. Competitive Demonstrations (the Demonstration/Validation Phase): The alternative system design concepts selected for consideration for competitive demonstration are submitted in DoD to the Secretary of Defense. His approval of this submission constitutes DSARC milestone one, the beginning of the demonstration/validation phase. Competitive demonstrations are intended to verify that the chosen concepts are sound, perform in an operational environment, and provide a basis for selection of the system design concept(s) to be continued into full-scale development. Such demonstrations normally involve some type of prototype. The resulting concept(s) and contractor(s) of the demonstration/validation phase may then more into full-scale development and initial production.

5. <u>Full-Scale Development, Test, and Evaluation</u> (the Full-Scale Development Phase): The contractors who successfully demonstrate their design concepts may be awarded contracts for subsequent full-scale development after the Secretary of Defense grants his approval at DSARC milestone two. During this phase, initial production units are manufactured, tested, and evaluated in an environment that assures effective performance under expected operational conditions.

6. <u>Production</u> (the Production Phase): Following satisfactory test results from the full-scale development phase, the Secretary of Defense may authorize full production at DSARC milestone three, the last DSARC milestone.

7. <u>Deployment and Operation</u>: As production systems become available, they are deployed into operational use, thereby providing the capability originally identified in the mission need statement. This new capability then becomes a factor in the continuing mission analyses of the agency, and the major system acquisition cycle continues.

It has been widely reported in the press that the current four-step DSARC process has just been changed by the new administration to a two-step process proposed by a panel chaired by Under Secretary of Defense Carlucci. This potential change is recognized as affecting this appendix, but should have minimal effect on the findings, conclusions and recommendations of this thesis.

APPENDIX B

STRUCTURED INTERVIEW QUESTIONS

1. What has been your association with the Mil-Prime developmental effort?

2. Have you written any Mil-Prime specifications, standards, or handbooks? Which ones?

3. Have you used any Mil-Prime specifications to develop an actual specification? If so, did you rigorously follow the Mil-Prime format, or did you use the Mil-Prime specification as a guide?

4. Is the Mil-Prime landing gear specification representative of other Mil-Prime specifications? If not, why not?

5. Does the C-X landing gear specification follow the Mil-Prime format? If not, why not, and how does it differ?

6. How was the Mil-Prime specification on which you worked developed?

7. How was the C-X landing gear specification developed?

8. What are the similarities between the traditional and Mil-Prime systems?

9. What are the significant differences between the traditional and Mil-Prime systems?

10. What problems, if any, do you expect Mil-Prime to solve?

11. What problems, if any, do you expect Mil-Prime to cause?

12. What will be the impact, if any, on future weapon systems?

13. Is Mil-Prime simpler to implement and to manage than the traditional system? If so, how is it simpler? If not, how isn't it as simple?

14. Is Mil-Prime more flexible to implement and manage than the traditional system? If so, how is it more flexible? If not, why isn't it as flexible?

15. Will Mil-Prime be well received by defense contractors? Explain.

16. How has the ASD engineering community responded to Mil-Prime?

17. How can the Mil-Prime system be improved?

18. Who else makes inputs, other than you, to the Mil-Prime specifications for which you are responsible?

19. What constitutes a requirement?

20. Do you see any difference between a requirement and a condition? If so, what?

21. What importance is the word "shall" in the requirement?

22. How would you measure simplicity in a specification?

23. How would you measure flexibility in a specification?

24. Is there anything else that you can tell us about Mil-Prime that you feel could be of interest to us?

APPENDIX C

INTERVIEWEE TITLE DESIGNATIONS

Program/Office	Job Title
Flight Systems Engineering	Aerospace Engineer
E-3/E-4 Vehicle Engineering Office	Flight Systems Engineer
Strategic Program Office	Mechanical Engineer
C-X Systems Program Office	Deputy Chief Engineer
Flight Systems Engineering	Technical Expert
Propulsion Program Office	Propulsion Engineer
Propulsion Program Office	Aerospace Engineer
Airlift Systems	Integration Engineer

SELECTED BIBLIOGRAPHY

A. REFERENCES CITED

1. Barlock, Major Lawrence A., USAF. "Project Engineer Guidelines for the Application of Specifications and Standards." Unpublished research report, Air Command and Staff College, Maxwell AFB AL, May 1974.

2. Blackledge, Ronald G. "A Study of Research and Development Contract Requirements and Their Growth." Unpublished doctoral dissertation, University of Texas, Austin TX, May 1979.

3. Dunn, Walter P. Aerospace engineer, Deputy for Engineering, HQ ASD, Wright-Patterson AFB OH. Personal interview. 8 April 1981.

4. Flanagan, James H. The Functions of Specifications. Natick MA: Office of the Scientific Director, U.S. Army Natick Laboratories, July 1969. AD700988.

5. Gray, Donald H. Flight systems engineer. Deputy for Engineering, HQ ASD, Wright-Patterson AFB OH. Personal interview. 22 April 1981.

6. Mahoy, James O., James F. Gill, Melvin Wiviott, and Edwin J. Smithson. Government Contract Law. 6th ed. Wright-Patterson AFB OH: Air Force Institute of Technology, March 1979.

7. "Making Tailoring Work," Defense Systems Management Review, Summer 1979, pp. 111-115.

8. Pollack, Henry. Mechanical engineer, Deputy for Engineering, HQ ASD, Wright-Patterson AFB OH. Personal interview. 15 April 1981.

9. Pratt, Major Robert J., USAF. Partitioning of Military Specifications and Standards. Ft. Belvoir VA: Defense Systems Management College, November 1977.

10. Puryear, William H. Department of Defense Specifications Development Guide (History, Purpose, Disciplines and Techniques). Ft. Lee VA: U.S. Army Logistics Management Center, December 1975.

11. Raimondi, E.J. Deputy chief engineer, C-X System Program Office, HQ ASD, Wright-Patterson AFB OH. Personal interviews. 6 November 1980 and 21 April 1981.

AD-A105 129 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/G 5/1
AN EVALUATION OF MIL-PRIME IN COMPARISON WITH THE TRADITIONAL S--ETC(U)
JUN 81 R T STEARMAN, W E WEBER
UNCLASSIFIED AFIT-LSSR-4-81 NL

2 OF 2
AD A
105 129

END
DATE
FILMED
10-81
DTIC

12. Shea, Joseph F., _et al_. _Report of the Task Force on Specifications and Standards_. Washington DC: Office of the Director of Defense Research and Engineering, April 1977.

13. Skantze, Lieutenant General Lawrence A., USAF. "How ASD is Meeting the Needs of the Nineties," _Air Force Magazine_, October 1980, pp. 37-43.

14. Strayer, Daniel E., and Lyle W. Lockwood. "What Are We Buying Here?" Unpublished report, Air Force Business Management Center, Wright-Patterson AFB OH, 1977.

15. Tremblay, Bruce. Technical expert, Deputy for Engineering, HQ ASD, Wright-Patterson AFB OH. Personal interviews. 30 October 1980 and 2 April 1981.

16. U.S. Department of Defense. "Military Standard Configuration Control--Engineering Changes, Deviations, and Waivers," _MIL-STD-480_. Wright-Patterson AFB OH: AFLC, 30 October 1968.

17. ________. "Specification Practices," _MIL-STD-490_. Andrews AFB MD: AFSC, 20 October 1968.

18. U.S. General Accounting Office. _Impediments to Reducing the Costs of Weapon Systems_. Washington DC: U.S. General Accounting Office, 8 November 1979.

19. U.S. Office of Federal Procurement Policy. "Major Systems Acquisitions: A Discussion of the Application of OMB Circular A-109." OFPP Pamphlet No. 1, Washington DC, August 1976.

20. Weingarten, Joseph L. "Aeronautical Procurement--the Primary Specification System." Attachment to ASD/EN letter dated 5 April 1979 to all ASD chief engineers, Wright-Patterson AFB OH.

21. ________. Plans and Programs engineer, Deputy for Engineering, HQ ASD, Wright-Patterson AFB OH. Personal interviews. 9 October 1980, 29 April 1981, and 11 May 1981.

B. RELATED SOURCES

Bauer, Charles. Propulsion engineer, Deputy for Engineering, HQ ASD, Wright-Patterson AFB OH. Personal interview. 13 April 1981.

Fox, Lester, and Jeffrey S. Allen. "Tailoring Specifications and Standards to Today's Needs," Defense Management Journal, October 1977, pp. 10-16.

Jordan, John E. Aerospace engineer, Deputy for Engineering, HQ ASD, Wright-Patterson AFB OH. Personal interview. 8 April 1981.

Logistics Management Institute. The Development of Requirements for Major Weapons Systems. Springfield VA: National Technical Information Service, July 1973. AD770826.

Mathews, Warren E. "Toward More Effective Implementation of Specification Tailoring," Defense Systems Management Review, Autumn 1978, pp. 15-22.

Shea, Joseph F. "Background of Study on Specifications and Standards," Defense Systems Management Review, September 1979, pp. 103-111.

Stimson, Richard A. "Correcting the Shortfalls in the Defense Specifications and Standards Program," Defense Management Journal, March-April 1979, pp. 19-23.

Wolf, John. Integration engineer. Deputy for Engineering, HQ ASD, Wright-Patterson AFB OH. Personal interview. 2 April 1981.